HIGHEST-ENERGY COSMIC RAYS AND HILBERTIAN REPULSIVE EFFECT

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Abstract. We point out that an important portion of the high energy of the cosmic rays from extragalactic sources can be attributed to a Hilbertian repulsive effect, which is a consequence of Einstein equations *without* cosmological term.

PACS 96.40 – Cosmic rays; 04.20 – General relativity.

Here is the abstract of a recent article on *Correlation of the Highest-Energy Cosmic rays with Nearby Extragalactic Objects* [1]: “Using data collected at the Pierre Auger Observatory during the past 3.7 years, we demonstrated a correlation between the arrival directions of cosmic rays with energy above 6×10^{19} electron volts and the positions of active galactic nuclei (AGN) lying within ~ 75 megaparsecs. We rejected the hypothesis of an isotropic distribution of these cosmic rays with at least a 99% confidence level from a prescribed a priori test. The correlation we observed is compatible with the hypothesis that the highest-energy particles originate from nearby extragalactic sources whose flux has not been substantially reduced by interaction with the cosmic background radiation [Greisen-Zatsepin-Kuzmin effect]. AGN or objects having a similar spatial distribution are possible sources.” And in the summary the authors write that “AGN have long been considered as likely sources of cosmic rays. Our data suggest that they remain the prime candidates.”

First of all, we remember that in astrophysics we know several boosting mechanisms for the charged particles, in particular the *magnetic reconnections* – *i.e.*, decaying magnetic fluxes –, and the *Fermi accelerations*: the motions in ionized gas clouds originate extended magnetic fields of low field strength in the interstellar spaces; charged particles passing through these clouds gain, in statistical average, more energy than they lose. Now, the cosmic rays with the highest energy are prevalently protons and heavier nuclei.

AGN activity requires nuclear burning and magnetic reconnections, as Kundt emphasizes [2]. According to a widespread belief, the core of the AGN would be a supermassive BH. However, we have proved ([3], [4]) that *if we take properly into account a hydrodynamical pressure $p = p(t)$*, any gravitational collapse of a spherosymmetrical material ends in a body with the ***finite*** radius $(9/8)2m$, if $m \equiv GM/c^2$ and M is the gravitating mass. In papers [4] and [5] we have illustrated the existence of a “Hilbert effect” [6], according to which in particular instances and in particular regions the

Einsteinian gravity – *without* the intervention of a cosmological term – exerts a ***repulsive*** action.

The differential equation of the *radial* geodesics of test-particles and light-rays in the Schwarzschild field of a gravitating centre has the following first integral ([4], [5], [6]):

$$\left(\frac{\mathrm{d}r}{c\,\mathrm{d}t}\right)^2 = \left(\frac{r-2m}{r}\right)^2 \left[1 + A\left(\frac{r-2m}{r}\right)\right] \quad , \tag{1}$$

where r is the *standard* radial coordinate. A is a constant which is zero for light-rays and negative for test-particles. For $(2/3) \leq |A| \leq 1$, we have two regions, the region in which the acceleration is negative (attractive gravity) and the region in which the acceleration is positive (*repulsive* gravity), according to the following values of the velocity:

$$\left|\frac{\mathrm{d}r}{c\,\mathrm{d}t}\right| < \frac{1}{\sqrt{3}}\,\frac{r-2m}{r} \quad , \quad \text{(attraction)} \quad ; \tag{2}$$

$$\left|\frac{\mathrm{d}r}{c\,\mathrm{d}t}\right| > \frac{1}{\sqrt{3}}\,\frac{r-2m}{r} \quad , \quad \text{(repulsion)} \quad . \tag{3}$$

In reality, the case $|A| = 2/3$ is a limiting case: the maximal value of $(\mathrm{d}r/c\,\mathrm{d}t)^2$ is $(1/3)$, at $r = \infty$, and the entire geodesic lies in a *repulsive* region. All the radial geodesics for which $\varepsilon \leq |A| \leq 2/3$ – where $\varepsilon > 0$ is an arbitrarily small quantity – belong entirely to a *repulsive* region. And we see that if $|A| = \varepsilon$, at $r = \infty$ we have $|\,\mathrm{d}r/\mathrm{d}t| = \sqrt{1-\varepsilon}\cdot c$! The following diagrams, where $x := r/2m$, and $y(x) := (\mathrm{d}r/c\,\mathrm{d}t)^2$, are of a great evidence.

For $x = 9/8$, we have $y(9/8) = (1/9)^2[1 - |A|(1/9)]$; if $|A| = \varepsilon$, we have $[y(9/8)]^{1/2} = (1/9)\sqrt{1-\varepsilon/9}$, *i.e.* $|\,\mathrm{d}r/\mathrm{d}t| = (1/9)\sqrt{1-\varepsilon/9}\,c$. This is the initial velocity v_0 of a test-particle $\boldsymbol{T}$ which arrives at $r = \infty$ with a velocity $\sqrt{1-\varepsilon}\,c$. If for $\boldsymbol{T}$ we take, *e.g.* a proton of a cosmic ray, we must answer the question: what mechanism did give it the remarkable velocity v_0 ? We think that the *magnetic reconnections* of the AGN generating the cosmic rays yield a boosting mechanism that is quite appropriate also from the *quantitative* point of view [2].

In conclusion, we set forth the assumption that an important portion of the enormous energy of the cosmic rays from extragalactic AGN can be attributed to a Hilbertian repulsive effect [7]. –

We are very grateful to our friend Dr. S. Antoci, who sent us a copy of the paper by the *Pierre Auger Collaboration*.

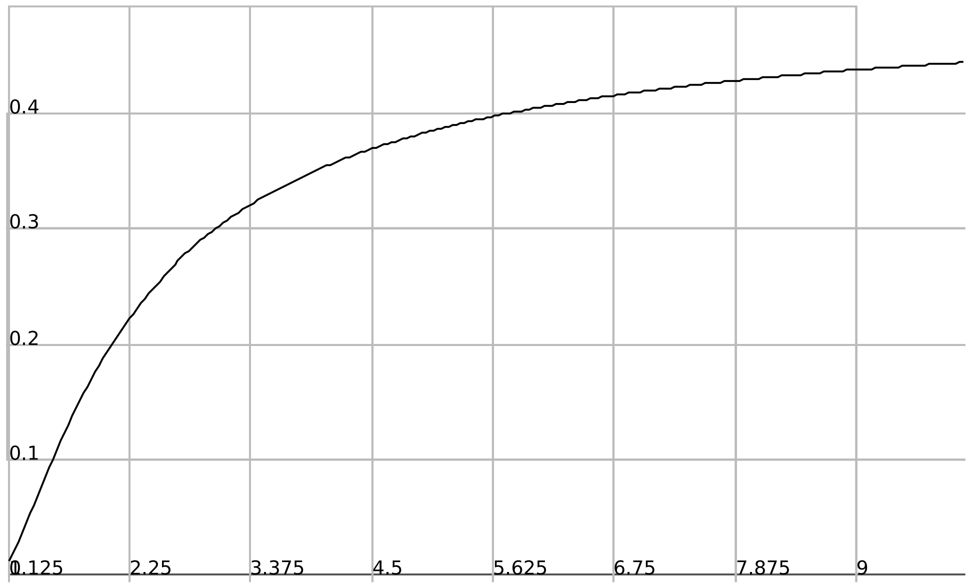

FIGURE 1.
Diagram of $y(x) = [(x-1)/x]^2[1 - 0.5 * (x-1)/x]$ for some values of x; $(9/8) \leq x < +\infty$; $\max(+\infty; 0.5)$; $[y(9/8)]^{1/2} = 0.107981$.

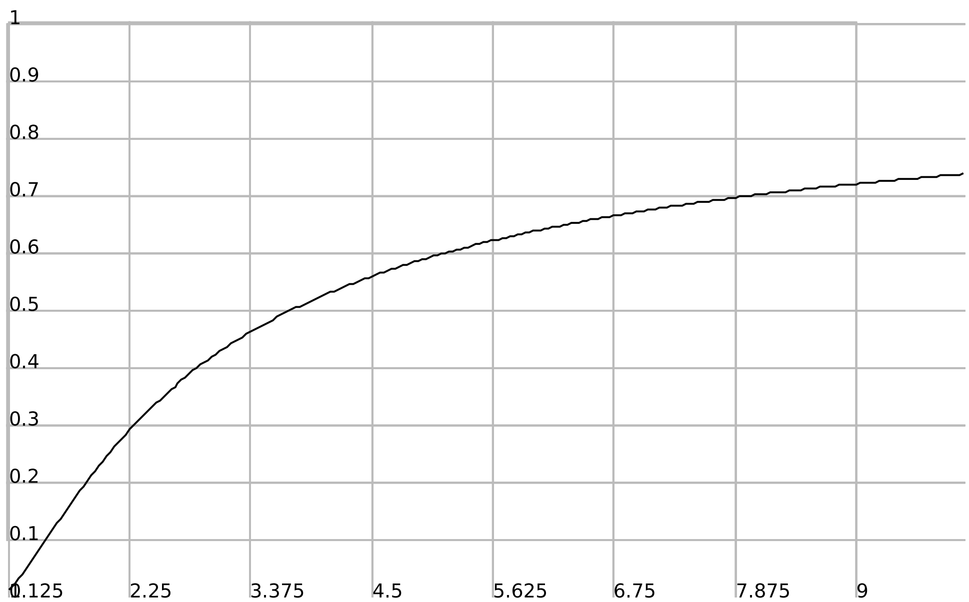

FIGURE 2.
Diagram of $y(x) = [(x-1)/x]^2[1 - 10^{-1} * (x-1)/x]$ for some values of x; $(9/8) \leq x < +\infty$; $\max(+\infty; 0.9)$; $[y(9/8)]^{1/2} = 0.110492$.

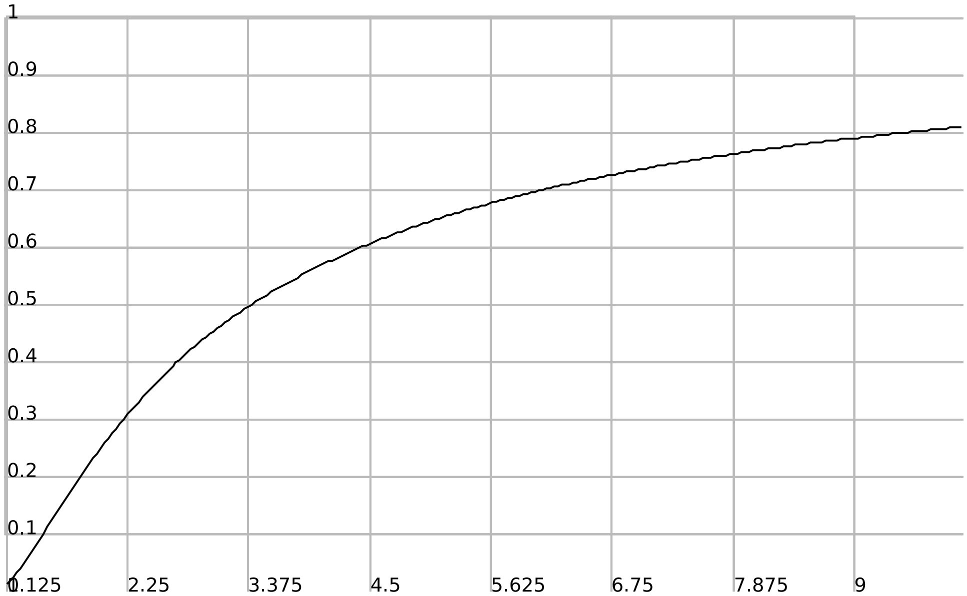

FIGURE 3.
Diagram of $y(x) = [(x-1)/x]^2[1-10^{-3}*(x-1)/x]$ for some values of x; $(9/8) \leq x < +\infty$; $\max(+\infty; 1-10^{-3})$; $[y(9/8)]^{1/2} = 0.111105$.

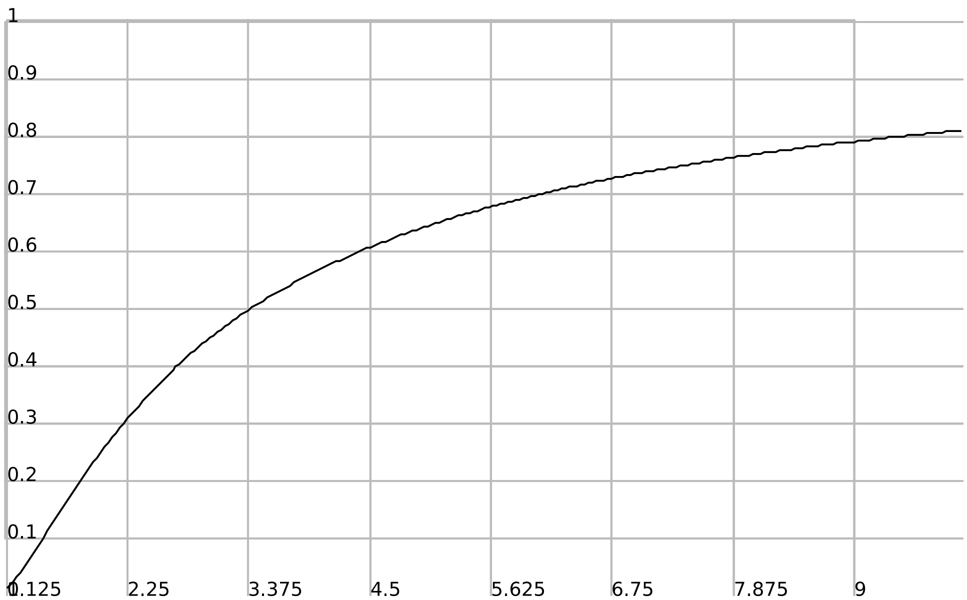

FIGURE 4.
Diagram of $y(x) = [(x-1)/x]^2[1-10^{-6}*(x-1)/x]$ for some values of x; $(9/8) \leq x < +\infty$; $\max(+\infty; 1-10^{-6})$; $[y(9/8)]^{1/2} = 0.111111$.

References

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[7] In the last paragraphs of sect.**2**.2 of his paper on *arXiv:gr-qc/0508048 v1* (11 Aug 2005) C. Frønsdal makes very general considerations about the relation between the Einsteinian manifold of a material point at rest and the emission of cosmic rays.

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